

Forecast Systems Laboratory Review

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Peer Review Team Member Report

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The Forecast Systems Laboratory is engaged in a broad spectrum of valuable research and development. This is clear, from both the presentations given at the Review and the material distributed to our team. Although broadly spread across system development, observing systems, and numerical modeling, the majority of efforts are directed to meet the needs of operational weather services. The management has been effective in stabilizing a reasonable funding balance (~ 43% base) and aggressively pursuing potentially valuable activities. At times during the review the efforts appeared unrelated, but I felt the Director did an excellent job of painting an overarching vision that encompassed most of the laboratory's efforts.

For some programs there appears to be less than desirable collaboration with other NOAA entities or groups involved in similar research. The rather weak link between FSL and the NWS is particularly frustrating given the direct match between FSL's focus and the responsibilities of the NWS. These are very broad and complicated issues that likely need to be solved within upper management of NOAA and the laboratories. I do not see any requirements for major changes in laboratory programs or emphasis. Nonetheless, there are several areas that raise some concern and need to be addressed.

I have organized my review into two parts, general comments and recommendations. The general comments part is structured according to the three broad topic areas identified by FSL management; namely, Information Systems, Observing Systems, and Atmospheric Data Assimilation and Numerical Prediction. As recommended, I have only commented on areas where I felt I had expertise and could identify specific points of emphasis. Omission of a specific project does not imply either endorsement or lack thereof

GENERAL COMMENTS:

INFORMATION SYSTEMS:

The work of FSL in developing and prototyping forecasting workstations has, without doubt, been invaluable to the National Weather Service in its recent deployment of AWIPS. The large investment that NOAA/NWS placed in FSL (and earlier in PROFS) to fund risk reduction activities has paid off. However, this successful technology transfer has not always been without doubt. To put it bluntly, the system nearly failed. It was only well into the procurement process, and after near crisis situations, that the years of development were effectively incorporated into AWIPS.

After this near failure, it is of great concern to hear FSL management speak casually about their fundamental philosophy of designing systems so contractors can build them. In this reviewer's opinion, the implementation of this philosophy is flawed and needs to be carefully evaluated. It is not apparent that anything has changed from previous projects, leaving ongoing efforts within FSL, e.g., FX-LINUX, only loosely connected to the NWS development plans. Without a better connection and cooperation between these two elements of NOAA, several things are at risk. First, resource investments within FSL can ultimately be wasted.

Second, the NWS is ill prepared to effectively incorporate this technology into its control and implementation once demonstrated to be advantageous.

It seems there must be some way to coordinate FSL development activities and NWS plans to better ensure an effective transfer of advances into the operational infrastructure. The idea that NOAA maintain a laboratory to conduct development and risk reduction activities that, once demonstrated to be effective, can be transferred to the operational arm of NOAA (and more broadly) is excellent. However, to ensure optimal use of limited Federal resources, NOAA has the responsibility to guarantee that these efforts are not wasted and procedures are in place that can effect an efficient transfer to the NWS.

The delayed and incomplete transfer of AWIPS to the National Weather Service has resulted in an unfortunate situation. Laboratory resources are being drawn away from desirable development activities to do rather mundane, trouble shooting activities on the currently installed AWIPS system. Although understandable given the history of the deployment, these activities should not be done within FSL. This is clearly mortgaging our future, and needs to be corrected. NOAA should find a quick way to develop the necessary infrastructure within the APO and PRC to enable them to take over much of these immediate activities, and un-encumber laboratory resources to address future capabilities and requirements.

One area that has apparently lost developers to short-term AWIPS issues is the IFPS development within the Enhanced Forecaster Tools Branch. The area of forecast preparation and dissemination remains one of the biggest obstacles to overcome as the NWS nears the completion of its modernization. Rapid prototyping and risk reduction activities have shown that current forecast preparation systems are still inadequate, particularly within areas of complex terrain. IFPS is a critically important effort within FSL and its resources need to be protected. In addition, it is not clear that efforts within NWS/TDL and FSL are complementary or coordinated. This appears to be another effort where communications between the NWS and FSL have been less than desirable. A presenter's remark that they were working from a "one line requirements statement from the NWS" underlines the apparent problem.

FX-NET appears to be a logical and effective extension of much of FSL's earlier workstation development activities and should be continued. This is an example of how FSL management has been able to develop its progressive vision through the discretionary use of base funds. FX-NET appears to have a huge potential impact on education, training, and applications.

Finally, it is encouraging to see that FSL is working on the next generation of operational forecasting systems, FX-LINUX. Although this reviewer is not familiar enough with software and hardware issues to either endorse or question the details of this effort, its scope is critically important. The estimated timing of completed system design by FY2004 appears disappointingly long. With realistic delays and cumbersome procurement activities, this could leave the NWS with aging equipment and capabilities. An additional concern is, once again, the lack of evidence that this effort is being closely coordinated with the management of the NWS. Clearly, there are other customers of FSL and the difficulty in becoming too tied to one specific group's requirements is appreciated. Nonetheless, it is in NOAA's best interest to keep these two groups reasonably well coordinated.

OBSERVING SYSTEMS:

The Forecast Systems Laboratory's participation in NAOS activities is very positive. Scientists have repeatedly identified these activities as highly important to determining future directions in observing and

atmospheric modeling. Unfortunately the necessary experiments are very expensive and as a result are not being conducted as quickly as one would like to see. FSL's decision to utilize a substantial part of newly acquired computing resources for NAOS activities is right on track and will ensure NOAA provide valuable scientific support to the broader meteorological community.

The ACARS project is a superb example of how development and execution of a promising resource was completed within FSL, marking a positive track record on technology transfer. These data are increasingly valuable to the operational community at forecast offices and national centers. This effort needs to continue as it explores options to measure moisture content. However, as the collection and processing of these data become more routine, the final residence of this program should be evaluated. The complementary development of GPS moisture measurements is also well founded.

GAINS appears to be a potentially valuable technology and is a reasonable investment of laboratory resources. At this point the potential gains of the effort balance the risks. However, this balance should be monitored with respect to both non-FSL efforts to design observing strategies for the global oceans and the laboratory's own successes in developing GAINS.

The profiler demonstration program is one of the programs that seems to have been orphaned by the operational community and budget committees. It is currently level funded and there is little indication that a national network is any closer to being installed. The resources necessary to change to the new frequency should be invested and this is most likely best carried out by FSL. However, if continued efforts to transfer this well demonstrated technology to the operational community fail, serious consideration should be given to eliminating this program.

ATMOSPHERIC DATA ASSIMILATION AND NUMERICAL PREDICTION:

The MAPS effort is a tremendous success story for FSL. Broad support from the FAA, FSL base, and NWS funds have worked to maintain a solid and continued development process. This has allowed a clear transfer of an operational system to the NWS (as RUC) for routine use. This has freed resources at FSL for continued development activities. I am aware that this process has not taken place without tremendous personal investment by FSL and NWS staff to foster the transfer. Nonetheless, there must have been lessons learned that can be utilized to help with those programs stuck in a state of incomplete transfer.

LAPS is FSL's effort to address a critically important challenge within the operational forecast community. The LAPS project within FSL, apparently eight scientists and nearly \$1.5M in funding, recognizes this importance but, with somewhat disappointing results. The current level of performance is only marginally improved over versions several years ago, which are known to have significant difficulty, especially in areas of complex terrain. Although it is difficult to speculate, it appears much of the LAPS resources have been used to keep up with platform transitions and specific demonstration deployments, depleting the resources necessary to tackle the very significant challenges presented by mesoscale objective analysis. As a result, other systems are approaching the sophistication and resolution of LAPS. Apparently, FSL is already experimenting with running MAPS at 13 km, which is comparable to the LAPS 10 km grid. FSL needs to consider what is the best use of these resources. If a decision is made to continue with LAPS, then efforts need to be made to direct resources toward solving the remaining fundamental problems in mesoscale analysis.

FSL's involvement in the WRF modeling effort is very encouraging. The fit of FSL into this development is perfect and should be exploited. Unfortunately NCEP's resources are still severely restricted. There are

some signs of improvement with NCEP's new SP having nearly 50% of its resources available for development. It makes sense to leverage FSL resources with those of the broad community in cultivating the WRF effort. This would improve the chances of success for the project and would be to the benefit of NOAA and meteorology in general. For FSL to strongly embrace this effort speaks to the quality of leadership within the laboratory. It might be in the best interest of the community for FSL to concentrate more on the WRF model than its own model development. We were told during the review that they are "behind the others" in their development efforts. These are difficult decisions, but at least the questions need to be raised.

RECOMMENDATIONS:

NOAA needs to find a quick way to develop the necessary infrastructure within the APO and PRC to enable them to take over much of these immediate activities and free up laboratory resources for development and rapid prototyping of future systems.

The LAPS effort should be either increased and focused to aggressively address the remaining troubling issues related to objective mesoscale analysis or reduced to only meet current obligations.

FSL should increase the IFPS effort and work closely with NWS management and TDL to establish realistic requirements. IFPS development resources that are being lost to short-term AWIPS 4.2 activities need to be protected.

Continue FX-NET and FX-LINUX activities.

FSL's continued involvement in the NAOS program is desirable, and if they could take a lead in establishing some of the early results, it would speak highly of the laboratory's vision and commitment to excellence.

If FSL is to embark on an intensive effort to work toward establishing the complete weather prediction system, it is critical that this effort be coordinated with the NWS and its vision.

It would be desirable to see stronger links between FSL and the USWRP efforts. The USWRP scientific foci represent the consensus vision of the scientific community and thus should be reflected in FSL decisions.

The Troika procedure should be evaluated to assess whether it is the optimal way to coordinate FSL and NWS activities.

Review of FSL

Greg Mandt

August 10, 1999

Overall Sense

I very much appreciate the opportunity to have participated in the FSL review. I haven't had the chance to see all the activities in a lab for some time and enjoyed seeing the great things which were presented. In the overall sense, I commend FSL for their professionalism and dedication to improving the nation's weather services. FSL has done an excellent job in developing a vision, carrying out the relevant research and working to transition that research to operations. They serve as the model for such activity in the NOAA lab system. Please take my following comments as suggestions for improving what is already a very good operation.

Comments on Purpose of the Review

It seems to me the purpose of the review could be improved by focusing the presentations on the base-funded activities. The review's primary purpose could then be to provide FSL information with which to evaluate the distribution of base funding. The external-funded activities could be presented in a very brief overview to demonstrate how you have combined the base and external activities into a coherent plan. Overall, however, my focus for the review was not so much on the scientific approach of the various activities but rather on how the activity looked from a couple of perspectives. First, I tried to evaluate if the ongoing research budget was being applied reasonably to meet the highest needs of the operational community. Second, I looked at how the transition from research to operations was being addressed.

Comments on Planning

In order to address these two perspectives, the first challenge was to understand the "big picture." While Sandy provided a good verbal summary of how the lab efforts fit together, it seemed to me that FSL should have a documented plan of how their activities relate. The "FSL In Review, 1998-1999" document you provided was organized along the structure of FSL. While this did give me an excellent summary of what was going on, it did not provide the unifying perspective I was looking for. The reason for developing a unifying message is to clearly communicate the relationship between operational needs and the lab's activities. The plan can juxtapose the operational priorities and the technological opportunities to build a strong case for the ongoing activities. One approach I have seen in other labs involves the use of technology roadmaps. This approach breaks the overall lab mission into a subset of technology areas. In FSL's case, the areas presented in the review (i.e., information systems, observing systems, atmospheric data assimilation and numerical prediction, and advanced computing) would certainly be appropriate. For each of these areas, the technology roadmap would consist of a number of summaries. First, the roadmap would contain a summary of the state of fielded capability for that area. A second element would be a summary of what technology limitations/opportunities are associated with the fielded capability. Another element would be an analysis of what research would have greatest payoffs. Finally, the roadmap would include a plan to focus the lab's research activities along the high payoff lines. Then the specific research activities carried out by FSL can be the paths by which operations can move forward to the vision of improved operations. This technology roadmap would 1) document the vision (and supporting rationale) for each technology area, 2) demonstrate how lab efforts are integrated in each area, and 3) lay out the path for the technology

transition to operations. By putting such effort into planning, FSL could more clearly communicate with its technology users. Speaking for the NWS, currently I see a few NWS personnel providing user feedback to the various research activities at FSL. However, with better defined planning activities, I think FSL could better dialog with the NWS (and other targeted technology users) on technology planning activities and with NWS senior management to improve understanding of the research activities resulting in improved technology transition.

Research Activity Comments

Information Systems: I consider the work in this area the most exciting and having the highest payoff. The WFO-Advanced software was critical for NWS modernization. Ongoing work in FX-LINUX has immediate potential to solve a current NWS CWSU workstation need and may prove vital for moving NWS to more affordable, upgradable workstations. I see the current difficulties we need to work on as: 1) FSL staff being bogged down with NWS forecaster requests for information and “bug” fixes, 2) FSL development activities potentially diverging from the NWS configuration managed system, and 3) potential duplication of development activities between FSL and NWS TDL (and perhaps WFO development activities). All three of these difficulties can be dealt with through closer planning activities between FSL and the NWS. The roadmap concept could prove very valuable for this coordination by clearly defining the interrelationship of activities and the planning effort. However, I am concerned that management of this major software evolution activity will be very difficult for us. Delivery of AWIPS into all our forecast offices has moved the NWS forecast process into the digital age. As we take advantage of this capability and begin to modernize our products, the potential for divergence is substantial. Somehow we need to develop a coherent, modern, software development process, incorporating the major software development capability of FSL and TDL but also allows for creative activities at 121 NWS forecast offices and the NCEP service centers.

Observing Systems: This area has been very difficult for the NWS to make improvements. The WSR-88D has been the latest observation improvement but getting the radar system was a long, difficult process. Getting new operational observing systems in place will be even more difficult. The difficulty is demonstrated by our lack of success to date in getting NWS funding for ACARS, profilers, upgraded radiosondes, and other improved observations. NESDIS has had more luck moving forward with satellite observation improvement. However, they are substantially aided by the fact that those observing systems can’t be maintained and have a definite end of life. Satellite purchases provide NESDIS an opportunity to add new technology. Better overall planning and cooperation between senior research and operational managers are needed to make headway in this area.

In general, I think the whole area of observations needs a more rigorous analysis to clearly document where we should go in this area. This would include a specific summary of what observations are made today, the limitations of those systems, and a statement of the most important observational needs (this would change over time with higher resolution models and improved data assimilation). This detailed information would bring additional credibility to observational research efforts. This is a specific example of how a technology roadmap would benefit overall planning and the communication of research priorities.

GAINS: The documentation on this system in “FSL in Review” states that GAINS balloons fill a void in the current global observing systems. The write up states the balloons would “anchor” satellite measurements. Currently NESDIS uses radiosondes for this “tuning” process. Would the balloons somehow improve this? Are these GAINS balloons seen as a replacement for the existing radiosondes? I did understand how

this system would ever be moved into operations. Does FSL plan to do more than just demonstrate one of these balloons? Has dialog begun with the NWS on planning to budget for such a system? I'm concerned that this project has the potential to get expanded to a point similar to the profiler network where a fair amount of resources will be spent maintaining a "subset" of needed capability with no clear path to getting a full system put into operations. Once the technology feasibility is demonstrated, a workable transition plan should be developed.

ACARS: A good example of FSL providing excellent development work to obtain a high quality, low cost set of observations. Now that it has been demonstrated, however, FSL should be putting its energy into obtaining the water vapor sensing system but should get NWS to totally carry the ball with respect to running/expanding the basic network. However, to show this isn't necessarily an easy task, it's illustrative to see how NWS funding for ACARS has worked the last few years. Basically the NWS has passed the hat internally to get funding for ACARS. Initiatives have been put in the budget but none have made it all the way through Congress yet (hope is still out for 2000!). My point is, given these difficulties for what should be a "no brainer", what hope do we have for the more substantial systems we would like to transition to NWS operations? We need better NWS/OAR planning to effect successful transition.

Profiler Network: As long as this is a separate line item from Congress, I suppose we should do what we can with the funding. However, continuing this effort potentially detracts from doing other creative things. FSL showed availability statistics of 90%, up from 70% when it was declared "operational." I don't think even the 90% is adequate for operations. Our survey team from the May 3 tornado outbreak told me they would like to see improved emphasis on maintaining the profilers. The continued lack of success in upgrading the profilers and getting them moved to NWS operations again highlights the need for serious evaluation of how to transition observing systems to operations. I would contend that despite your designation of the profiler network as "operational," they are really still in a demonstration status.

Atmospheric Data Assimilation and Numerical Prediction:

RUC: The RUC activities represent another good example of successful transition from research to operations. However, I wonder if there are still specific goals for continued research in the RUC. It seems to me the goal of developing a rapid update model been met. I had a number of questions in this area. A few follow. How long will FSL put resources into improving the RUC? How is the current development guided? Do the using communities provide specific input for improvement through some sort of review progress? Should specific model development (such as for this rapid update model) perhaps be focused only on the models strength - i.e. rapid updating - as opposed to general model performance? How do competing requirements get sorted out? I guess my point is I don't see an overall plan for this specific model or an analysis on what resources this consumes and if this is the best application of FSL's model development activity.

Overall, I wonder how much activity is being put into all the modeling efforts at FSL? I am very intrigued by the concept of the community model. It looks like substantial efficiency could be gained if our combined efforts were directed at a common community model. The presentation showed the WRF as funded through USWRP. This suggests FSL isn't taking a leadership role in this. I would think a numerical modeling roadmap would reveal the excellent potential of such an activity and result in a redirection of base funding and scientific talent into this exciting and high payoff activity.

Aviation Gridded Forecast System and RTVS: These are good efforts and show good cooperation with the NWS Aviation Weather Center. I am concerned that these efforts need better coordination with overall

NWS aviation needs. I will work to get my folks working closer with FSL to ensure all parts of the NWS aviation program are communicating with FSL.

Advanced Computing: These activities appeared reasonable in support of FSL activities. My only reaction was to Joan Brundage's Data Repository presentation. These efforts may benefit from better understanding of NWS plans in this area. Joan was aware of some of our efforts with NCDC and the training archiving efforts NWS/COMET has worked on but I don't think she had the whole picture of NWS archiving plans/deliberations in the AWIPS era. FSL and NWS could perhaps both benefit from collaboration in this area.

Review of the Forecast Systems Laboratory

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1. General Comments

This review focused on the scientific and technical activities of the Forecast Systems Laboratory. The discussion of management, leadership, interaction with the cooperative institutes, and diversity was limited.

The mission of the Forecast Systems Laboratory is to develop and transfer products and services that contribute to a complete weather prediction system. The Laboratory has a very strong record of accomplishments, most notably for its contribution to AWIPS for which it has received numerous awards. The very nature of its mission demands that the Laboratory be forward looking, invest in a variety of exploratory solutions, and be able to adapt rapidly to changes in NOAA mission requirements. This also requires that the customer for new services participate actively in the process of defining requirements, establishing milestones and defining the path from development through to operational acceptance.

The Laboratory's primary customer is the National Weather Service, which it supports through the development of observing systems, information systems, advanced computing and atmospheric assimilation and modeling. The Laboratory's base funding is divided into three areas, the broad area of weather research, and two major focused efforts, the profiler network and high performance computing. The bulk of the additional NOAA funds support AWIPS. About 20% of the total budget is from non-NOAA sources with the largest fraction from the FAA. In general all of these efforts support the NOAA programs and help underwrite the core activities of the Laboratory.

FSL is a well-directed Laboratory that adheres closely to its mission and is responsive to the NOAA strategic plan. However, a broad vision of the laboratory, the long-range goals and how each of the research elements presented to the reviewers fit together was less clear. The most significant problem is the lack of a well-developed path to take advantage of the transitional systems developed at FSL. It is not clear that this is an FSL problem alone, but rather a strategic problem within NOAA, which prevents timely transitions or termination of redundant projects. The transition from development to operations is not particularly clear in NOAA, leading to the development of a number of systems that are mature, but still supported by FSL (e.g., the profiler demonstration program) with no timeline for transition or termination. While support continues for these efforts, they lock up intellectual capital, perhaps preventing the Laboratory from moving ahead in other fundamental areas.

The need to support AWIPS through development to implementation forced the Laboratory to develop a contractual management style. This role continues as the Laboratory provides operational support for AWIPS. This limits the resources available to devote to new systems. That they have created an excellent product is noted, but much of their expertise may be underutilized in a support role rather than in exploratory development.

In these examples, it is unclear whether the customer (NWS) has the necessary program to accept systems developed on their behalf. Much of the efforts of the OAR Laboratories appear to develop in a piecemeal

fashion without the necessary oversight and guidance to ensure that the research intended for NOAA customers will transition. This results in a rather ad hoc approach to system development often without the necessary commitments from customers.

The relationship between FSL and other OAR laboratories was not discussed in detail. It is difficult to assess the extent of the overlap, competition and cooperation between FSL and other OAR laboratories.

RECOMMENDATION: A process is required that better defines the pathway from development to operational acceptance.

2. Specific Comments

a. Evidence of accomplishments

FSL has a strong record in exploratory development. It has received considerable accolades for work on AWIPS and there appears to be considerable customer satisfaction evinced by the DOC medals awarded to AWIPS and RUC-2. However, although a leading laboratory at the forefront of new and innovative technical solutions to weather research and forecasting problems, it has a surprisingly poor peer reviewed publication record. While it may be argued that the focus of the laboratory on transitioning technology to operations does not lend itself to traditional accomplishment measures, the dissemination of high quality research to the broadest community can be best achieved through publication. I note that less than a dozen atmospheric scientists, mathematicians and technical specialists have contributed to journal articles in recent years. The reviewers were not aware of performance measures applied to each of the research areas. These measures could determine where peer reviewed publications are expected, where conference proceedings are the norm, and where the transition and acceptance of computer codes and systems are more acceptable. More effort should be put into turning conference proceedings into journal articles.

RECOMMENDATION: Better defined performance measures that emphasize dissemination of advancements to the broader research community through peer reviewed journals where appropriate.

b. Selected Research Activities

1) AWIPS

AWIPS has been a great success. A clearer path is needed to allow FSL to focus on the long-term evolution of the system rather than operational support. Though stated in the review, it is not clear how this will happen since it requires the active involvement and commitment of the weather service. OAR Headquarters needs to pay attention to these activities to ensure that OAR resources (intellectual as well as financial) are not unnecessarily tied up supporting weather service operational activities. I reiterate the recommendation made in the general comments:

RECOMMENDATION: The pathway from development to operations needs to be more clearly defined with the hand-over to operational support completed in a timely fashion.

2) FX-Net, FX-Linux

FX-net and FX-Linux are major innovations that have the potential to increase the availability of forecast

information via the Internet and provide lower cost servers for full feature weather forecast systems, respectively. The latter is intended as a candidate to replace the existing forecast tools in the weather service. Both innovations are clearly of benefit to the university teaching and research community, but may also help SME sector weather services focused on specific regional and local applications.

RECOMMENDATION: Maintain momentum for this research effort and seek potential user input at the earliest possible opportunity.

3) GLOBE

The Global Learning and Observations to Benefit the Environment (GLOBE) program is a US led international effort to enhance environmental awareness particularly amongst school students. More than 7000 schools participate in over 80 countries. The US GLOBE Program, which involves NASA, NSF, and EPA in addition to NOAA, provides the program infrastructure, including the development of the science and education materials and the operation of the data servers necessary for reporting and archiving data and creating and providing images. International partner provides their own in-country support and management of GLOBE activities.

This is a valuable program that strives to provide the necessary scientific training to teachers and provides hands-on observational scientific experience for school students. GLOBE is a major effort that goes a long way to addressing the problems of science education in our school system. The program appears to be well run. Though educational it appears to lack strong university interest, which could be remedied through the OAR cooperative institutes to tie the program to university K-12 outreach activities. That CIRA plays a significant role in the FSL effort is noted. The joint institutes offer the opportunity to expand GLOBE to the total environment including stronger geophysical and oceanographic elements, for example.

RECOMMENDATION: OAR should take the initiative to use its joint institutes to reach out into university K - 12 programs to enhance the program within the US.

4) The North American Observing System Program

The NAOS program is critical to the development of the optimum mix of observations for the next century weather service and significant FSL participation is warranted; indeed, it is essential to accomplish this task. The NAOS program should be a very high priority to ensure that the Laboratory is influential in the design of new observing systems, both in situ and satellite. The program must stay ahead of model developments to ensure that the observing system is optimized for the next generation of higher-resolution numerical models, whose data requirements may be more exacting than at present.

RECOMMENDATION: While not responsible for the entire effort, FSL should try to ensure that sufficient resources are available to this effort so that it can influence the design of future numerical weather system tools, such as the WRF, before requirements are set.

RECOMMENDATION: It would be beneficial to marine forecasting to assess the value of additional off-shore measurements to provide guidance to other observing system developments within OAR.

5) Global Air-Ocean In-situ System (GAINS)

This system proposes a network of stratospheric balloons capable of deploying dropsondes and other sen-

sors. This is an innovative and interesting research effort with the potential to provide observations in data sparse regions of the world. Existing research efforts, such as NORPEX, are demonstrating the value of targeting data sparse regions over the ocean to improve forecasts over North America. This system could provide a cost-effective platform to obtain these data routinely.

The system is in a test phase with demonstrations and assessments planned for 2004. However, it is not too early to consider the criteria required for adoption of such a system operationally. It was not clear during the review whether there is active involvement of the weather service to determine operational feasibility of the concept.

RECOMMENDATION: Maintain momentum for this research effort to demonstration phase.

6) Profiler Network

(i) Wind Profiler

The basic radar profiler network is a mature system that has been successfully demonstrated by FSL. The network has been fully operational since 1992. This is a very successful program, which should be expanded to a larger portion of the country and should transition to operational services. Cooperation with ETL on NDBC buoy mounted systems should be encouraged. It is not clear whether maintenance of the routine system detracts from new profiler developments - new architecture, frequencies, etc. it would appear that the congressional mandated for this program may impede transition in favor of a state of perpetual development.

RECOMMENDATION: Develop timeline for transition to operational NWS

RECOMMENDATION: Expand system to cover larger portion of the country

RECOMMENDATION: Participate in the development and testing of NDBC mounted profilers under development at ETL

(ii) GPS Water Vapor

Water vapor is a critical measurement, which is generally under-sampled or poorly sampled. The GPS water vapor network has demonstrated the retrieval of accurate total column water vapor from GPS sites. The program has benefited greatly from advances in GPS geodesy, and the presence of the demonstration profiler network to test and evaluate the system. It is a very good example of a collaborative effort between the university community and the laboratory, and leveraging other FSL research efforts. It has the great potential of providing data in sparse ocean regions following the recent demonstration of GPS retrievals from moving platforms, such as buoys. The possibility of obtaining the vertical distribution of water vapor from GPS is very exciting and will lead to numerous advances both in the operational forecasting and research communities.

RECOMMENDATION: There is the great potential for a large payoff from this system, continued development of this activity should be encouraged with expansion to ocean areas.

RECOMMENDATION: Broader university cooperation should be encouraged in this endeavor.

7) Numerical Modeling

FSL is developing and operates several model systems. While these seem duplicative, they represent an effort to pursue the best technologies for future operational systems. The presentations focused on various advances in each of these systems. It would have been beneficial, however, to have viewed some of these developments from the perspective of the user. For example, a presentation of the application of the RUC in the weather service by forecast personnel would have been helpful. In the context of this effort, the mechanism to get NWS requirements into FSL was not clear. Similarly, how does the idea of local modeling in AWIPS for all WFOs fit with NWS policy?

RECOMMENDATION: The WRF model represents a major commitment to the next generation forecast model. FSL has a major role to play in this effort.

RECOMMENDATION: The present effort appears well directed, it is hoped that more resources will be available to contribute to the fullest extent possible.

RECOMMENDATION: Clarify OAR research modeling activities across all laboratories to avoid unnecessary duplication and improve cooperation.

c. Relationship with Joint Institutes and other OAR Laboratories

It was unfortunate that the directors of CIRA and CIRES were not part of this review considering the large traction of JI personnel involved in FSL research. The growing dependence on the Joint Institutes for staffing makes it increasingly important to consider the JI directors as part of the management team for review purposes. The unintended result of this omission gave the impression to this reviewer, at least, that the lab considered the Joint Institutes as a source of personnel rather than as partners. The lab is increasingly a group of senior federal managers supervising work conducted largely by Joint Institute or contract employees. The advantage of the relationship with the university community through the Joint Institutes does not appear to be exploited particularly well or at the very least, it was not highlighted well in the review. I was left with the impression that Joint Institute staffing is simply cheaper than are contract employees.

The extent of the partnerships with other OAR laboratories was difficult to discern. It is not clear whether there is any unnecessary duplication of effort, or if increased cooperation could improve research activities within OAR. Some of the skills that are unique to FSL may be particularly useful to other labs and vice versa. The likely increase in ocean prediction research within the next ten years could benefit greatly from the technical innovation of FSL.

RECOMMENDATION: Better definition of the partnerships between FSL and the Joint Institutes is warranted

RECOMMENDATION: Better integration of OAR laboratory research efforts to maximize the benefits of cooperation.

Douglas H. Sargeant
July 31, 1999

Scientific and Technical Review

NOAA Forecast Systems Laboratory

I consider the NOAA Forecast Systems Laboratory (FSL) to be an extremely valuable national asset in which NOAA and DOC can take great pride. In the relatively short time since its creation, FSL has dramatically improved NOAA's effectiveness in introducing rapidly evolving science and technology into operational services that benefit the nation. FSL has accelerated the timeliness of adapting new and better systems, and has improved the cost-effectiveness of both research and operations. At the same time, FSL has achieved national and international recognition for its excellence and unique capabilities, and has been in demand to help other U.S. and foreign agencies to employ modern science and technology. The innovative FSL staff has created and integrated entirely new systems and methods, and has designed and conducted both developmental and operational demonstrations, which have strongly influenced how weather observing, analysis, forecasting, and dissemination are done today.

FSL played a critical role in the design and implementation of NOAA's National Weather Service Modernization and Restructuring (MAR) program. The pioneering work of FSL and its precursors in the development and exploitation of modern information system technology to acquire, process, access and display vast amounts of environmental information provided one of the seeds that emboldened the NWS to undertake a radical redirection of its human and financial resources to improve services. Through exploratory development and demonstration of functional prototypes, FSL's work guided the preparation of requirements and specifications for the AWIPS system, permitted early examination of operational impacts of the @ and eventually supplied the core interactive applications software that enables the field forecasters to perform their restructured jobs.

Concurrently, FSL pioneered in the identification, fostering and real-time acquisition and use of high-resolution observational data needed to resolve the atmospheric mesoscale in space and time. Examples are various forms of environmental satellite data and ACARS data from commercial aircraft. One product of FSL's efforts to assimilate such information frequently (a few hours vs. twice per day) in an analysis-forecast cycle was the development of the MAPS, which was adapted by FSL for use by the NWS/NMC/NCEP as the Rapid Update Cycle (RUC). Another was the development of the LAPS, whose analysis components have been adapted for AWIPS. In fact, the entire Local Data Acquisition and Dissemination functionality of AWIPS has its roots in the groundbreaking work of FSL.

Dissemination of products and information is often considered a neglected area of NWS modernization, in part because it's so challenging. It was never neglected by FSL, and several seminal ideas of new product types and dissemination methods resulted from exploratory development by FSL. Such work has been slowed by diversion of FSL talent to AWIPS integration and testing, but this should be an area of fruitful contribution by FSL in the future.

A closely related and perhaps more fundamentally difficult area of FSL development is the application of advanced information system technology to support the human-computer interactive preparation of forecast products (so-called IFP). While impressive accomplishments have been made by FSL in this area, both the need and opportunity for further progress are enormous. It is not an exaggeration to say that NWS modernization and restructuring cannot fully succeed as planned without completing the developments long planned by FSL (but also diverted in the past year or two).

Even a very selective list of notable FSL accomplishments would be flawed by not mentioning the Profiler project. Working closely with the creative scientists in its sister laboratory (now ETL), FSL has demonstrated one of the most remarkable improvements in routine, nearly continuous, accurate quantitative observations of tropospheric profiles ever achieved. This technology for obtaining vertical profiles of wind is now quite mature and ready for operational deployment. It is somewhat surprising that decision makers have not found NOAA's justifications for moving forward convincing yet. The RASS temperature soundings are more limited but still impressive and cost-effective. The innovative use of a network of ground-based GPS receivers is extremely promising. The example extraction of the tropospheric humidity field using variational analysis that was presented at the review is exciting and deserves close attention.

I am aware that FSL has received recognition and awards for its accomplishments from several organizations, including NOAA and DOC, the *Smithsonian*, *Popular Science*, and others. OAR is no doubt more aware of such recognition than I. The seeking out of FSL and the transfer of funds by NWS, NESDIS, DOD, FAA, NASA, Taiwan and others is convincing evidence of their respect for and confidence in FSL. More subtle, FSL is constantly visited, routinely consulted and invited to meetings and conferences by the active participants and users of FSL's fields of expertise.

Based on the documentation provided, it appears that FSL is conscientiously endeavoring to fulfill its approved mission and the expectations in the NOAA and DOC strategic plans. I am concerned that these goals and visions for FSL are not ambitious enough, that they may not take full advantage of the capabilities of FSL in the context of NOAA's broad mission, and that they may not sufficiently challenge FSL to do all that it can do. In particular, FSL's expertise in observing, analysis, modeling and information science and systems are largely applicable to the oceans and climate. FSL did point out the potential applicability of the proposed GAINS initiative to these areas, but potential contributions of FSL are much wider. Featuring FSL participation in an initiative for COAPS on the cover of the latest FSL annual report was encouraging.

Having mentioned GAINS, I will comment on it here as I have some familiarity with the concepts and technology due to their examination in the Global Atmospheric Research Program years ago. I consider GAINS a good example of an innovative proposal to address central issues in the effectiveness and cost of obtaining global observations suitable for modern numerical models and necessary for answering key question about the earth system. The prospect of obtaining routine, high quality soundings with familiar characteristics over oceans and other sparsely observed areas at modest cost is extremely attractive. Such information could greatly enhance the utility of remote sensing data from satellites, thereby leveraging a very large investment. Remarkable advances in the technologies of materials; satellite location, data collection and communications; and on-board and ground-based computer processing, amply justify the modest and cautious exploration that FSL has undertaken.

The fact that FSL is becoming mature was more obvious to me at this review than ever before. This shows up in various ways. For one, there are a number of fairly large, thoroughly conceived, active projects supported by experienced and dedicated staffs. Some of these are of clear high priority to NOAA and the nation and fully deserve continued development by FSL. Others have been carried to a rather mature stage of development and demonstration by FSL and are ready for operational implementation. They may be no less important to NOAA and the nation, but they are diverting scarce FSL development resources to routine operations and maintenance. An example of this is the Profiler Demonstration Network.

This is a classic problem for development organizations. They are often victims of their own success. Innovative people can be consumed by long-term care and feeding of their progeny. The problem is

exacerbated because the creators are susceptible to arguments that nobody else knows enough to do it except them, and because some senior developers have difficulty maintaining the same creative level and interest throughout their careers. They become comfortable with their largely completed products. To support continuing maintenance, new developments are delayed or displaced, or additional funding is required.

A common justification for maintaining a successful system developed in-house is that it is essential for the internal activities of the developing organization (even though the original justification may have been for transfer to operations). This argument could be made for the Profiler Demonstration Network, as profiler data are widely used in FSL development of analysis, modeling, decision, and display systems. Nevertheless, it is just a matter of time before obsolescence, temporary frequencies, etc. make it unfeasible or very costly to continue. It would be better for NOAA to plan and implement a phase-over to operations or a phaseout.

A similar consideration applies to the various analysis and prediction systems with their associated models and assimilation schemes. These seem to be accumulating by inertia and accretion. In response to questions, Sandy and FSL staff said they intended to shift more FSL resources over time to the community WRF model development. This seems sensible to me. Several projects using LAPS technology are externally funded. While this does not directly divert FSL discretionary funds, it does consume development and management talent that could be allocated elsewhere, even within the analysis and modeling subarea. NOAA and FSL management should attempt to allocate, on a priority basis, a level or proportion of resources for analysis and modeling, and to determine a “best mile” within that allocation. Not everyone capable of it needs to have their own model.

From an even more general perspective, several review panel members (including myself) expressed views that FSL’s program seemed to comprise a large and diverse collection of separate projects with the unifying themes not very apparent. Sandy responded that FSL’s work depends on exploitation of the best applicable science and technology, and that there are many candidates, continually evolving and changing. In order to make informed assessments and choices, he believes that FSL must have some hand-on experience with “all of them”. While there is some hyperbole in this, it is a rational approach and consistent with FSL’s exploratory philosophy. The FSL track record of being out in front justifies a balanced pluralism in selecting technical approaches. For example, the work on the LINUX, FX-NET, high speed networking and computing (including massively parallel processors) appears well justified. Uninformed managers could not make better choices, and inaction or waiting for others would not serve NOAA’s or the nation’s interests as well as FSL’s relatively inexpensive explorations. They help keep FSL near the cutting edge.

Another signal that came through between the lines at the review was that the intimacy of FSL’s relationships with actual or intended customers is somewhat uneven. I know from experience that a focused, continual interaction between the operational customer and the developer is essential to achieve a mutually acceptable result within planned resources. For many years I was a representative of FSL’s NWS customer. The extent of success and satisfaction by both organizations is very sensitive to this, and half a continent separation makes it more difficult. The assignment of senior, trusted NWS personnel to work on Sandy’s team was a key to success in this relationship. The routine collaboration with the Denver Forecast Office was another critical factor in verifying requirements and obtaining feedback. The recent co-location of the Forecast Office in the Skaggs Building with FSL should further promote these essential interactions. (Incidentally, a quick tour suggests that the new FSL facilities were very well thought out and executed. They should make FSL even more efficient and productive. My congratulations to OAR and NOAA for seeing this through despite the challenges.)

Returning to customer relationships, FSL also has provided important support to NCEP. I believe an extended visit by Ron McPherson to Boulder also was critical to successful transfer of MAPS to NMC. The future of the AWIPS collaboration and the MAPS/RUC/WRF collaboration depends on continual renewal of close interactions. However, close interactions with end users is not enough. I am aware that FSL's excellent collaborations with the Aviation Weather Center in Kansas City, largely supported by the FAA's Weather Research Program, were not always understood or appreciated by individuals at NCEP headquarters in the Washington area.

Maintaining effective relationships between FSL and its customers is very much a two-way street, and can't be fully controlled by FSL. OAR must demand and ensure that customers like NWS fulfill their essential role as well as FSL.

The relationship with customers outside NOAA is somewhat different. Other organizations want to capitalize on the investments NOAA and FSL have made. The national interest and NOAA's interests must be balanced. Sandy often expresses a policy of seeking strong mutual interests, e.g., finding what the other organization wants that FSL needs to do anyway. The added resources allow work to be accomplished faster and/or better. This is sound, but difficult to apply. The realities of decisions in a complex organization like the U.S. Government sometimes face managers like Sandy with awkward choices such as accepting outside work or disrupting a carefully built and productive team. The crisis may be short-lived (or so hoped). Such events are more likely for organizations like FSL with a relatively large fraction of onetime and outside funds.

While Sandy reported that his budget situation is better now than previously, OAR and NOAA should be aware and constructively helpful when unexpected fluctuations in FSL income occur. I do not believe there is any single "correct" fraction for "base" funds, but probably 3/4 of the budget should be stable from year to year. While contractors and Joint Institutes provide some flexibility, it is limited. Concerning what should be in FSL's base, even within NOAA there is merit in having the customer office be responsible for justifying and directing the use of funds that are critical to its own mission. This also helps to insure greater interest and accountability by the customer.

Turning to FSL's mission again, why should FSL continue to exist? It's official mission as a "technology transfer" laboratory within NOAA is valid but inadequate by itself. I have already expressed the view that the focus on weather analysis and forecasting, while important and successful, is probably too narrow. Other key NOAA mission and service areas such as oceans and climate should be included. But what then distinguishes FSL from OAR or NOAA?

I believe that FSL's uniqueness, expertise, and future value lie in its role as a comprehensive scientific systems laboratory devoted to the end-to-end process for providing the environmental information and products needed by NOAA's users (customers). This process entails observations, analysis, modeling, forecasting, product preparation, and dissemination. It requires related activities such as archiving, verification, and quality control. It makes use of theory, computation, professional practices and expertise (experience). It intensively employs observing and information technologies, including high performance computing, telecommunications and networking. FSL's role is to explore, selectively develop, integrate, test and demonstrate end-to-end systems that incorporate a judicious balance of all the essential elements, subject to constraints on performance, cost, and efficiency. This is a mission of great national importance worthy of NOAA, OAR, and FSL.

It is clear from this formulation that I believe FSL should, as planned, devote significant resources to helping NOAA (and others) systematically make large investment choices in the context of end-to-end systems. The NAOS program is an excellent example of a program directed toward this end for the crucial subarea of upper air observations. This area was deliberately deferred during NWS modernization planning, and upgrades may soon become desperate (and expensive). It is entirely appropriate that Sandy serve as chair of the NAOS Council and FSL devote significant computing and human resources to this problem.

After reviewing the materials from the review and reflecting on the discussions, I recognize that Sandy fully appreciates and is trying to fulfill the mission outlined above. The selection of the broad themes Information Systems, Observing Systems, Atmospheric Data Assimilation and Numerical Prediction, and Advanced Computing demonstrates this comprehensive viewpoint. My appeal for a better high-level, unifying theme for FSL is more a suggestion for better articulation and more explicit promotion of the mission by FSL, OAR, and NOAA. I'm sure Sandy could use some help from OAR on this.

Speaking of Sandy, the ERL Letter asked for comments on the quality of leadership and administration of the Laboratory. In short, it is top notch. NOAA is extremely fortunate to have someone with his talent, energy, wisdom and dedication to head FSL. He is truly extraordinary in breadth, depth and productivity. FSL has other leaders of extremely high quality, too many to mention without inadvertently on-fitting some. Nevertheless, Tom Schlatter's skills were evident in the review, and I have worked very closely in the past with Dennis Walts, Carl Bullock, and Mark Mathewson in Modernization Division. They are exemplary of the outstanding leadership and management talent in FSL.

While most of the topics listed in the ERL letter have been covered above, a few have not been addressed directly. The FSL publication record has been mildly controversial since before the laboratory was created. Especially when positions were graded or promotions considered, publication rates of individuals that fell below previous ERL norms raised questions and concerns. Eventually, it was recognized that the type of work many FSL scientists and engineers were engaged in was not appropriate for reporting in the usual refereed journals. Development, test, and demonstration of operational software and systems was not a widely recognized discipline. Also, much of the work progressed faster than publication cycles. The software and system components themselves were often the relevant products of the work, and they were in great demand. The presentation of conference papers was and remains an effective mechanism for exchange of much of the information about FSL's progress. In recent years, with web-type publication taking hold and broader interest in systems-oriented development, more effective dissemination of FSL results should be possible.

Regarding diversity, FSL has made a visible effort not only to draw talent from whatever sources are available, but also to create opportunities to attract and develop talent from under represented groups. The presentations at the review included several by women and minorities in positions of responsibility and authority. While the handout table of federal employees by diversity groups is respectable, it probably significantly understates the minority representation in the sixty percent of the FSL team not counted there. These include a wide range of people from the Joint Institutes, contractors, and other countries and institutions. Using all of these sources, FSL has achieved a dynamic and productive critical mass.

The question of the balance between vision and resources has many dimensions. Like almost all NOAA laboratories (and other NOAA organizations), FSL could do more if additional resources were available. The list of new initiatives proposed clearly demonstrates this. On the other hand, FSL is doing an excellent job of tailoring its programs to whatever resources are available. It is also aggressive and effective in

finding and earning a share of available resources. In my opinion, NOAA's and the nation's investments in FSL are resulting in very high returns. FSL's efforts to acquire additional resources warrant every serious consideration based on their outstanding track record to date.

Review Report of the NOAA Forecast Systems Laboratory

Warren M. Washington

26 July 1999

I took part in the Program Review as an observer for the NOAA Scientific Research Board. Although I was not required to provide a review, I felt that after taking part in the review that I could offer some independent views as a scientist from NCAR.

My overall impression is that the research and technology development at the Forecast Systems Laboratory (FSL) continues to be exciting and innovative. I believe the leadership management provides guidance to the staff and flexibility to pursue different approaches. I believe this entrepreneurial approach is important to their past success and that a more heavy-handed directorship approach would lead to less innovation. Any FSL activity will have a chance of failure but that is to be expected in any innovative activity. I was not critical of the fact that the FSL has had to depend upon a sizable fraction of non-NOAA funding sources. This is the reality, especially since NOAA is, in my opinion, an underfunded agency and there are many activities that need to be addressed given its broad mandate. This situation is not likely to improve in the near future. In most cases, the non-NOAA activities have contributed to the NOAA mission by providing a staff capable of providing expertise to NOAA related missions of FSL.

There is always the question of how can FSL driven technology be more effectively transferred to the operational parts of NOAA. Means must be found to have more "face-to-face" interactions with the operational elements of NOAA. This may mean more FSL talks, short visits, and videoconferences with the operational centers. This is as important as a purely contractual type of relationship.

Over the last few years one of the very important activities for FSL is the rescue of the AWIPS development. This is a vivid example of the wisdom of having such a group with their expertise. I am very pleased that they have moved into the use of Linux workstation capability, which greatly broadens the use of this technology. I might add there is another example that FSL is leading. They have pioneered in the early use of parallel computers for modeling and analysis. Their wise investment in acquiring early expertise is paying off at present and with the computer upgrade there will be more opportunity to enhance research in the future.

I would like to comment on some specific activities that are not necessarily in the order of importance.

1. There were some concerns expressed about too many overlapping modeling efforts. I am not overly concerned about this except to say that every so often on, say, a five year time scale that some sort of evaluation take place that sorts out the most promising approaches. This will require phasing out the less productive or dead end approaches. History of modeling has shown that there needs to be constant innovation and testing.
2. With respect to the NOAA strategic plan, I believe the FSL plays a unique role in the search for better ways to use data, technique development and enhancing modeling capability. The FSL work is well recognized but perhaps not always understood by the operational components of NOAA.
3. Concern was also expressed about the publication pattern. Apparently, after the last review the journal publications went up and now they have come down a bit. There are likely reasons such as a growing

senior staff that has more management responsibility' It is clear that FSL has not kept up with the hiring of younger scientists and engineers and that this could cause long-term problems. This, of course, is a NOAA wide problem. These issues were discussed at the exit meeting with the senior staff of FSL.

Finally, as a member of the NOAA Scientific Advisory Board (SAB) I have found taking part in the FSL review a rewarding experience. I must say, however, it should be expected that Board members could always be present for such reviews. SAB is in the process of defining how it will become involved in the review process. I have found it useful to have some experience on such a review committee.